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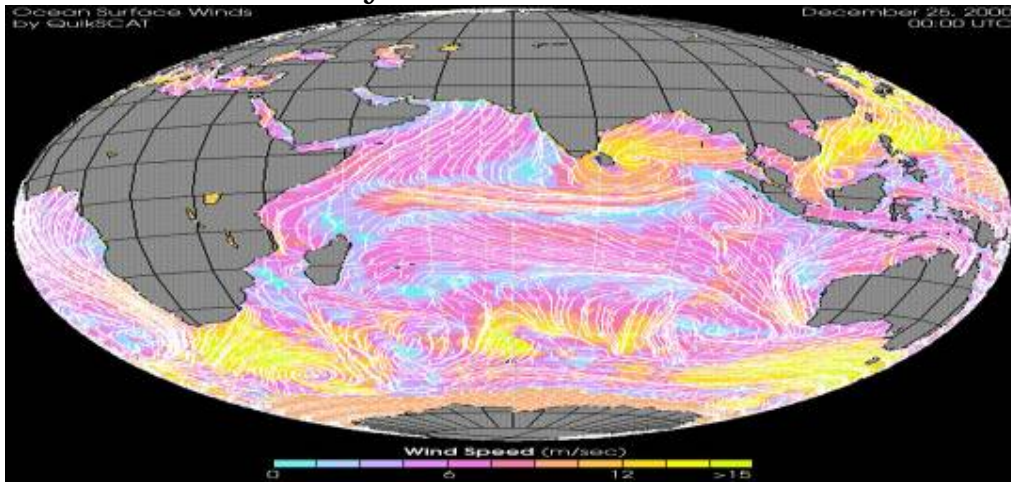
# World-systems in the Biogeosphere: Three Thousand Years of Urbanization, Empire Formation and Climate Change

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Ocean surface winds

**Abstract:** World-systems are human interaction networks that display oscillations of expansion and contraction, with occasional large expansions that bring formerly separate regional systems into systemic intercourse with one another. These waves of expansion, now called globalization, have, in the last two centuries, created a single integrated intercontinental political economy in which all national societies are strongly linked. This paper investigates the “pulsations” of regional interaction networks (world-systems) in Afroeurasia over the past 3000 years. The purpose is to determine the causes of a fascinating synchrony that emerged between East Asia and the distant West Asian/Mediterranean region, but did not involve the intermediate South Asian region. The hypothesized causes of this synchrony are climate change, epidemics, trade cycles, and the incursions of Central Asian steppe nomads. This paper formulates a strategy of data gathering, system modeling, and hypothesis testing that can allow us to discover which of these causes were the most important in producing synchrony as the Afroeurasian world-system came into being.

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## Outline:

World-Systems are interaction networks

Nested Networks of Information, Trade and Warfare

Core/Periphery Relations

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## **The rise of globalization within Afroeurasia**

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### **Central Asian Steppe Nomad Incursions**

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## **Testing the Model**

In Kurt Vonnegut's *The Sirens of Titan* a traveler from another solar system has crash-landed on one of the moons of Jupiter and is using his last bit of fuel to beam forces onto the Earth in order to send a message home. His efforts induce the Central Asian steppe nomads to behave in a way that causes successive Chinese states to build the Great Wall in the form of a script that appears from space as a rescue plea. This trope of distant forces affecting human history is an ironic tool in the hand of the fiction-smith who pokes fun at us for our hapless intentions. World historians have hypothesized other powerful mechanisms by which macrosocial processes may have been shaped by exogenous forces.

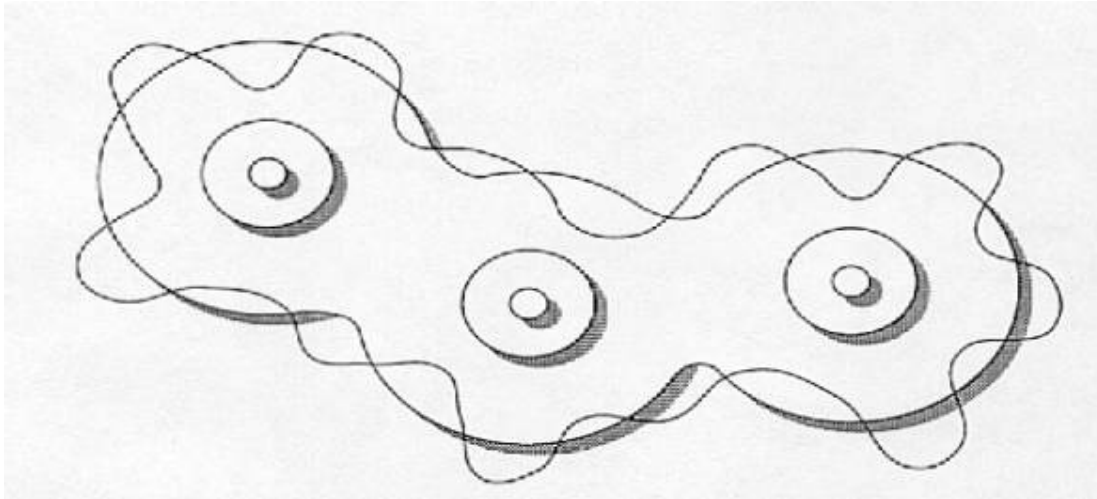
Since Ellsworth Huntington's *Climate and Civilization* there has been a growing literature on how spatial and temporal variation in rainfall, temperature, prevailing winds and episodic weather extremes have influenced the course of history. Archaeologists routinely invoke climate change as the explanation for social and cultural developments. As much more has been learned about the patterns of global weather these accounts have become more sophisticated. Bryan Fagan's (1999) *Floods, Famines and Emperors: El Nino and the Fate of Civilizations* is the most recent and compelling version. But instead of painting the humans as inert victims of powerful forces, Fagan argues that climate change has acted as the critical spur that pushed people to invent and implement radical new ways of interacting with nature and with one another.

Mike Davis's (2001) *Late Victorian Holocausts: El Nino Famines and the Making of the Third World* depicts how droughts caused by El Ninos in the nineteenth century interacted with the rapid integration of peripheral regions into global markets in a context of colonialism and

neocolonialism to bring about unprecedented huge famines and epidemic disease fatalities in Brazil, India, China and the Phillipines.

There is also an important literature about how human action may affect the climate. Much of this is focused on anthropogenic global warming in the twentieth century, but there is also a literature on how deforestation, irrigation building and land-use patterns have affected local weather (e.g. Chew 2001). And a growing research tradition on urban ecology has discovered the phenomenon of the “urban heat island,” an example of anthropogenic effects on the local weather (Gallo n.d.).

World-systems are human interaction networks that display oscillations of expansion and contraction, with occasional very large expansions that bring regional systems into contact with one another. These waves of expansion, now called globalization, have, in the last two centuries, created a single integrated intercontinental political economy in which all national societies are strongly linked. This paper investigates the “pulsations” of regional interaction networks (world-systems) in Afroeurasia over the past 3000 years. The purpose is to determine the causes of a fascinating synchrony that emerged between East Asia and the distant West Asian/Mediterranean region, but did not involve the intermediate South Asian region. The hypothesized causes of this synchrony are climate change, epidemics, trade cycles, and the incursions of Central Asian steppe nomads. This paper formulates a strategy of data acquisition, system modeling, and hypothesis testing that can allow us to discover which these causes were the most important in producing synchrony as the Afroeurasian world-system came into being.[\[1\]](#)



Three world-systems merge their prestige goods and information networks.

One limitation of some regional analyses has been the tendency to define regions in terms of homogenous attributes, either natural or social. Thus comparative civilizationists have tended to focus on the core cultural characteristics that are embodied in religions or world-views and to construct lists of culturally defined civilizations that then become the “cases” for the study of social change. Another approach that defines regions as areas with homogenous characteristics is the “culture area” perspective developed by Carl Sauer and his colleagues (e.g. Wissler 1927). This project gathered information on all sorts of cultural attributes --languages, architectural styles, technologies of production, kinship structures, etc. -- and used these to designate bounded and adjacent “culture areas.”

A major problem with both the civilizationist and cultural area approaches is the assumption that homogeneity is a good approach to bounding social systems that are evolving. Heterogeneity rather than homogeneity has long been an important aspect of human social systems. The effort to bound systems as homogeneous regions obscures this important fact. Spatial distributions of homogeneous characteristics do not bound separate social systems. Indeed, social heterogeneity is often **produced** by interaction, as in the case of core/periphery differentiation. Even sophisticated approaches that examine distributions of spatial characteristics statistically must make quite arbitrary choices in order to specify regional boundaries on this basis (e.g. Burton 1995).

The world-systems approach focuses instead on **human interaction networks**, and so it is able to define its units of analysis as systemic combinations of very different kinds of societies. This makes it possible to study multicultural systems and core/periphery relations as cases that can display dynamics of social evolution.<sup>[2]</sup>

The relationship between natural regions and human interaction networks is an important focus of theory and research. Cultural ecology has stressed the important ways in which local ecological factors conditioned sociocultural institutions and modes of living. This was an especially compelling perspective for understanding small-scale systems in which people were mainly interacting with adjacent neighbors not very far away. But this kind of local ecological determinism is much less compelling when world-systems get larger because long-distance interaction networks

and the development of larger scale technologies enable people to impose socially constructed logics on local ecologies. Some social evolutionists have interpreted this to mean that social institutions have become progressively less ecologically determined (e.g. Lenski, Lenski and Nolan 1995). But what has happened instead is that the spatial scale of ecological constraints have grown to the point where they are operating globally rather than locally (Chase-Dunn and Hall 1998).

### Spatially Bounding World-Systems

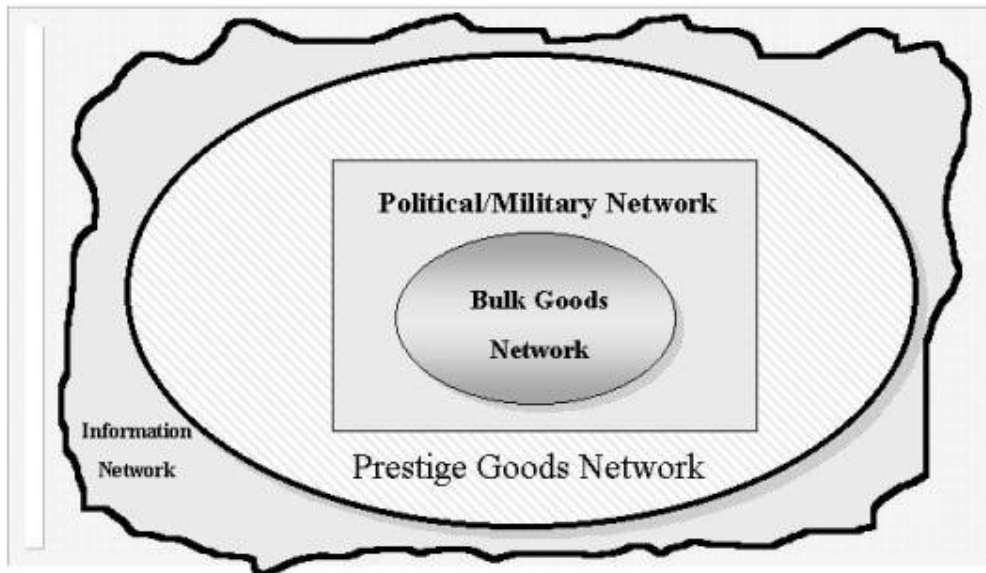
The world-systems perspective emerged as a theoretical approach for modeling and interpreting the expansion and deepening of the European system as it engulfed the globe over the past five hundred years (Wallerstein 1974; Arrighi 1994; Chase-Dunn 1998;). The idea of a core/periphery hierarchy composed of "advanced" economically developed and powerful states dominating and exploiting "less developed" peripheral regions has been a central concept in the world-systems perspective. In the last decade the world-systems approach has been extended to the analysis of earlier and smaller intersocietal systems. Andre Gunder Frank and Barry Gills (1993) have argued that the contemporary world system is a continuation of a 5000-year old system that emerged with the first states in Mesopotamia. Chase-Dunn and Hall (1997) have modified the basic world-systems concepts to make them useful for a comparative study of very different kinds of systems. They include very small intergroup networks composed of sedentary foragers (e.g. Chase-Dunn and Mann 1998), as well as larger regional systems containing chiefdoms, early states, agrarian empires and the contemporary global political economy in their scope of comparison. The comparative world-systems perspective is designed to be general enough to allow comparisons between quite different systems. Chase-Dunn and Hall (1997) define world-systems as important networks of interaction that impinge upon a local society and condition social reproduction and social change. They note that different kinds of interaction often have distinct spatial characteristics and degrees of importance in different sorts of systems. And they hold that the question of the degree of systemic interaction between two locales is prior to the question of core/periphery relations. Indeed they make the existence of core/periphery relations an empirical question in each case, rather than an assumed characteristic of all world-systems. Spatially bounding world-systems necessarily must proceed from a locale-centric beginning rather than from a whole-system focus. This is because all human societies, even nomadic hunter-gatherers, interact importantly with neighboring societies. Thus if we consider all indirect interactions to be of systemic importance (even very indirect ones) then there has been a single global world-system since humankind spread to all the continents. But interaction networks, while they were always intersocietal, have not always been global in the sense that actions in one region had major and relatively quick effects on distant regions. When transportation and communications were over short distances the world-systems that affected people were small. Thus it is necessary to use the notion of "fall-off" of effects over space to bound the networks of interaction that importantly impinge upon any focal locale. The world-system of which any locality is a part includes those peoples whose actions in production, communication, warfare, alliance and trade have a large and interactive impact on that locality. It is also important to distinguish between endogenous systemic interaction processes and exogenous impacts that may importantly change a system but are not part of that system. So maize diffused from Mesoamerica to Eastern North America, but that need not mean that the two areas were part of the same world-system. Or

a virulent microparasite might contact a population with no developed immunity and ravage that population. But such an event does not necessarily mean that the region from which the microparasite came and the region it penetrated are parts of a single interactive social system. Interactions must be **two-way and regularized** to be socially systemic. One-shot deals do not a world-system make.

Chase-Dunn and Hall (1997) note that in most intersocietal systems there are several important networks of different spatial scales that impinge upon any particular locale:

- Information Networks (INs)
- Prestige Goods Networks (PGNs)
- Political/Military Networks (PMNs), and
- Bulk Goods Networks (BGNs).

The largest networks are those in which information travels. Information is light and it travels a long way, even in systems based on down-the-line interaction.<sup>[3]</sup> These are termed Information Networks (INs). A usually somewhat smaller interaction network is based on the exchange of prestige goods or luxuries that have a high value/weight ratio. Such goods travel far, even in down-the-line systems. These are called Prestige Goods Networks (PGNs). The next largest interaction net is composed of polities that are allying or making war with one another. These are called Political/Military Networks (PMNs). And the smallest networks are those based on a division of labor in the production of basic everyday necessities such as food and raw materials. These are Bulk Goods Networks (BGNs). Figure 1 illustrates how these interaction networks are spatially related in many world-systems.



**Figure 1: Nested Interaction Networks**

The first question for any focal locale is about the nature and spatial characteristics of its links with the above four interaction nets. This is prior to any consideration of core/periphery position because one region must be linked to another by systemic interaction in order for consideration of core/periphery relations to be relevant.

The spatial characteristics of these networks clearly depend on many things - the costs of transportation and communications, and whether or not interaction is only with neighbors or there are regularized long-distance trips being made. But these factors affect all kinds of interaction and so the relative size of networks is expected to approximate what is shown in Figure 1. As an educated guess we would suppose that fall-off in the PMN generally occurs after two or three indirect links. Suppose group A is fighting and allying with its immediate neighbors and with the immediate neighbors of its neighbors. So its direct links extend to the neighbors of the neighbors. But how many indirect links will involve actions that will importantly affect this original group? The number of indirect links that bound a PMN are probably either two or three. As polities get larger and interactions occur over greater distances each indirect link extends much farther across space. But the point of important fall-off will usually be after either two or three indirect links.

Chase-Dunn and Hall (1997) divide the conceptualization of core/periphery relations into two analytically separate aspects:

- core/periphery differentiation, and
- core/periphery hierarchy.

Core/periphery differentiation exists when two societies are in systemic interaction with one



another and one of these has higher population density and/or greater complexity than the other. The second aspect, core/periphery hierarchy, exists when one society dominates or exploits another. These two aspects often go together because a society with greater population density/complexity usually has more power than a society with less of these, and so can effectively dominate/exploit the less powerful neighbor. But there are important instances of reversal (e.g. the less dense, less complex Central Asian steppe nomads exploited agrarian China) and so this analytical separation is necessary so that the actual relations can be determined in each case.<sup>[4]</sup> The question of core/periphery relations needs to be asked at each level of interaction designated above. It is more difficult to project power over long distances, and so one would not expect to find strong core/periphery hierarchies at the level of Information or Prestige Goods Networks. Figure 2 illustrates a core/periphery hierarchy.

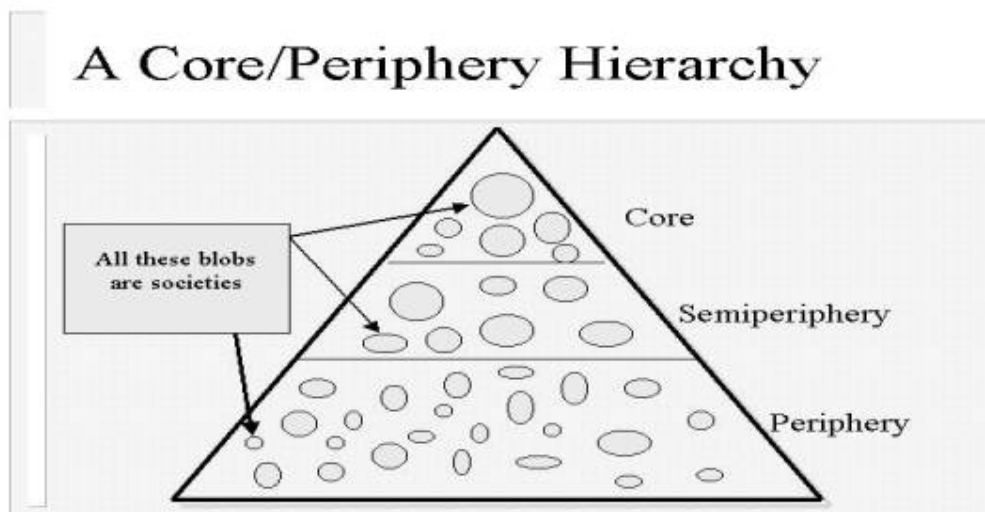
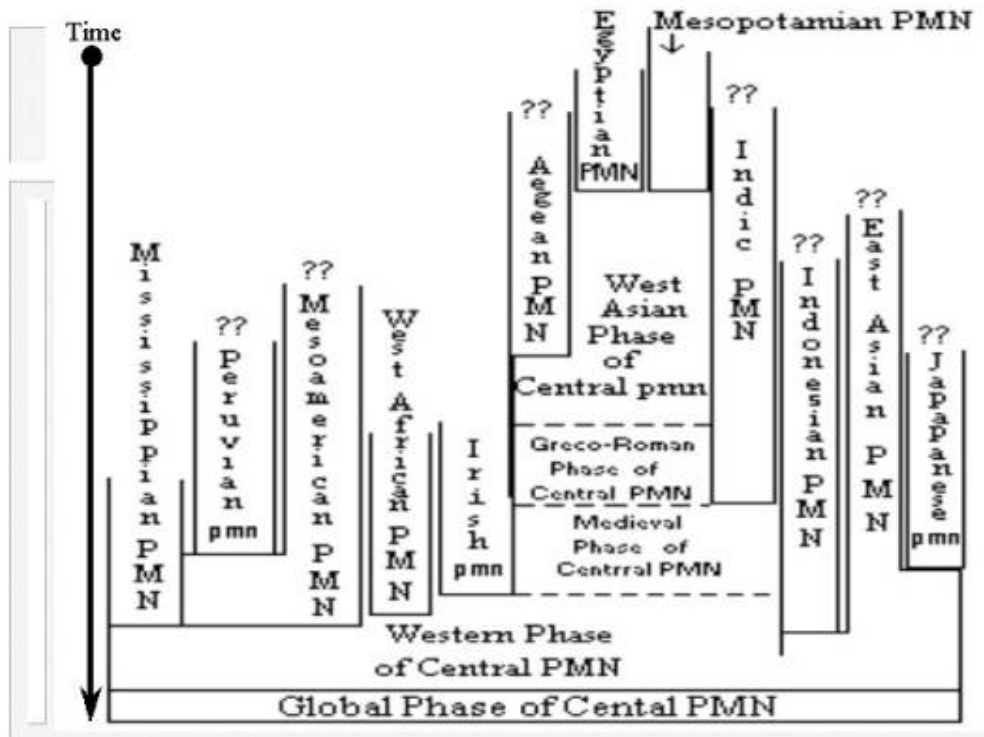


Figure 2: Core/Periphery Hierarchy

Core/periphery hierarchies are important in processes of social evolution because semiperipheral societies, those that are intermediate between core regions and peripheral hinterlands, are fertile locations for institutional innovations and frequently are the key actors that transform the developmental logic of world-systems. Chase-Dunn and Hall (1997:Chapter 5) call this “semiperipheral development.” Semiperipheral marcher chiefdoms conquer more senior and older core chiefdoms to form larger and more centralized complex chiefdoms, as do the much better know semiperipheral marcher states (e.g. Chin China, Assyria, Achaemenid Persia, Alexandrian Macedonia, Rome, Islamic Arabia, and the Ottoman Empire). Semiperipheral capitalist city-states (the Phoenicians, the Italian city-states, the Hanse cities, Malakka) were the agents of commercialization in the interstices of the tributary empires. In the modern world-system it has been the semiperipheral and capitalist Dutch republic, England and the United States of America that have risen to hegemony and further globalized the organization of the world economy. Semiperipheral development is still an important pattern in the twentieth and twenty-first centuries (Chase-Dunn and Boswell 2002).

Using the conceptual apparatus for spatially bounding world-systems outlined above we can construct spatio-temporal chronographs for how the interaction networks of the human population changed their spatial scales to eventuate in the single global political economy of today. Figure 3 uses PMNs as the unit of analysis to show how a "Central" PMN, composed of the merging of the Mesopotamian and Egyptian PMNs in about 1500 BCE, eventually incorporated all the other PMNs into itself.



Chronograph of the Rise of the Central System

Figure 3: Chronograph of PMNs [adapted from Wilkinson (1987)]

## World-system Cycles: Rise-and-Fall and Pulsations

Comparative research reveals that all world-systems exhibit cyclical processes of change. There are two major cyclical phenomena: the **rise and fall** of large polities, and **pulsations** in the spatial extent and intensity of trade networks. "**Rise and fall**" corresponds to changes in the centralization of political/military power in a set of polities – an "international" system. It is a question of the relative size of, and distribution of, power across a set of interacting polities. The term "cycling" has been used to describe this phenomenon as it operates among chiefdoms (Anderson 1994).

All world-systems in which there are hierarchical polities experience a cycle in which relatively larger polities grow in power and size and then decline. This applies to interchiefdom systems as well as interstate systems, to systems composed of empires, and to the modern rise and fall of hegemonic core powers (e.g. Britain and the United

States). Though very egalitarian and small scale systems such as the sedentary foragers of Northern California (Chase-Dunn and Mann, 1998) do not display a cycle of rise and fall, they do experience pulsations.

All systems, including even very small and egalitarian ones, exhibit cyclical expansions and contractions in the spatial extent and intensity of exchange networks. We call this sequence of trade expansion and contraction **pulsation**. Different kinds of trade (especially bulk goods trade vs. prestige goods trade) usually have different spatial characteristics. It is also possible that different sorts of trade exhibit different temporal sequences of expansion and contraction. It should be an empirical question in each case as to whether or not changes in the volume of exchange correspond to changes in its spatial extent. In the modern global system large trade networks cannot get spatially larger because they are already global in extent.<sup>[5]</sup> But they can get denser and more intense relative to smaller networks of exchange. A good part of what has been called globalization is simply the intensification of larger interaction networks relative to the intensity of smaller ones. This kind of integration is often understood to be an upward trend that has attained its greatest peak in recent decades of so-called global capitalism. But research on trade and investment shows that there have been two recent waves of integration, one in the last half of the nineteenth century and the most recent since World War II (Chase-Dunn, Kawano and Brewer 2000).

The simplest hypothesis regarding the temporal relationships between rise-and-fall and pulsation is that they occur in tandem. Whether or not this is so, and how it might differ in distinct types of world-systems, is a set of problems that are amenable to empirical research.

Chase-Dunn and Hall (1997) have contended that the causal processes of rise and fall differ depending on the predominant mode of accumulation. One big difference between the rise and fall of empires and the rise and fall of modern hegemonies is in the degree of centralization achieved within the core. Tributary systems alternate back and forth between a structure of multiple and competing core states on the one hand and core-wide (or nearly core-wide) empires on the other. The modern interstate system experiences the rise and fall of hegemonies, but these never take over the other core states to form a core-wide empire. This is the case because modern hegemonies are pursuing a capitalist, rather than a tributary form of accumulation.

Analogously, rise and fall works somewhat differently in interchiefdom systems because the institutions that facilitate the extraction of resources from distant groups are less fully developed in chiefdom systems. David G. Anderson's (1994) study of the rise and fall of Mississippian chiefdoms in the Savannah River valley provides an excellent and comprehensive review of the anthropological and sociological literature about what Anderson calls "cycling," the processes by which a chiefly polity extended control over adjacent chiefdoms and erected a two-tiered hierarchy of administration over the tops of local communities. At a later point these regionally centralized chiefly polities disintegrated back toward a system of smaller and less hierarchical polities.

Chiefs relied more completely on hierarchical kinship relations, control of ritual hierarchies, and control of prestige goods imports than do the rulers of true states. These chiefly techniques of power are all highly dependent on normative integration and ideological consensus. States developed specialized organizations for extracting resources that chiefdoms lacked -- standing

armies and bureaucracies. And states and empires in the tributary world-systems were more dependent on the projection of armed force over great distances than modern hegemonic core states have been. The development of commodity production and mechanisms of financial control, as well as further development of bureaucratic techniques of power, have allowed modern hegemons to extract resources from far-away places with much less overhead cost.

The development of techniques of power have made core/periphery relations ever more important for competition among core powers and have altered the way in which the rise-and-fall process works in other respects. Chase-Dunn and Hall (1997:Chapter 6) argued that population growth in interaction with the environment, and changes in productive technology and social structure produce social evolution that is marked by cycles and periodic jumps. This is because each world-system oscillates around a central tendency (mean) due both to internal instabilities and environmental fluctuations. Occasionally, on one of the upswings, people solve systemic problems in a new way that allows substantial expansion. We want to explain expansions, evolutionary changes in systemic logic, and collapses. That is the point of comparing world-systems.

The multiscale regional method of bounding world-systems as nested interaction networks outlined above is complimentary with a multiscale temporal analysis of the kind suggested by Fernand Braudel's work. Temporal depth, the *longue duree*, needs to be combined with analyses of short-run and middle-run processes to fully understand social change. The shallow presentism of most social science and contemporary culture needs to be denounced at every opportunity.

A strong case for the very *longue duree* is made by Jared Diamond's (1997) study of original zoological and botanical wealth. The geographical distribution of those species that could be easily and profitably domesticated explains a huge portion of the variance regarding which world-systems expanded and incorporated other world-systems thousands of years hence. Diamond also contends that the diffusion of domesticated plant and animal species occurs much more quickly in the latitudinal dimension (East/West) than in the longitudinal dimension (North/South), and so this explains why domesticated species spread so quickly to Europe and East Asia from West Asia, while the spread south into Africa was much slower, and the North/South orientation of the American continents made diffusion much slower than in the Old World Island of Eurasia.

The diagram below depicts the coming together of the East Asian and the West Asian/Mediterranean systems. Both the PGNs and the PMNs are shown, as are the pulsations and rise and fall sequences. The PGNs linked intermittently and then joined. The Mongol conquerors linked the PMNs briefly in the thirteenth century, but the Eastern and Western PMNs were not permanently linked until the Europeans and Americans established Asian treaty ports in the nineteenth century.

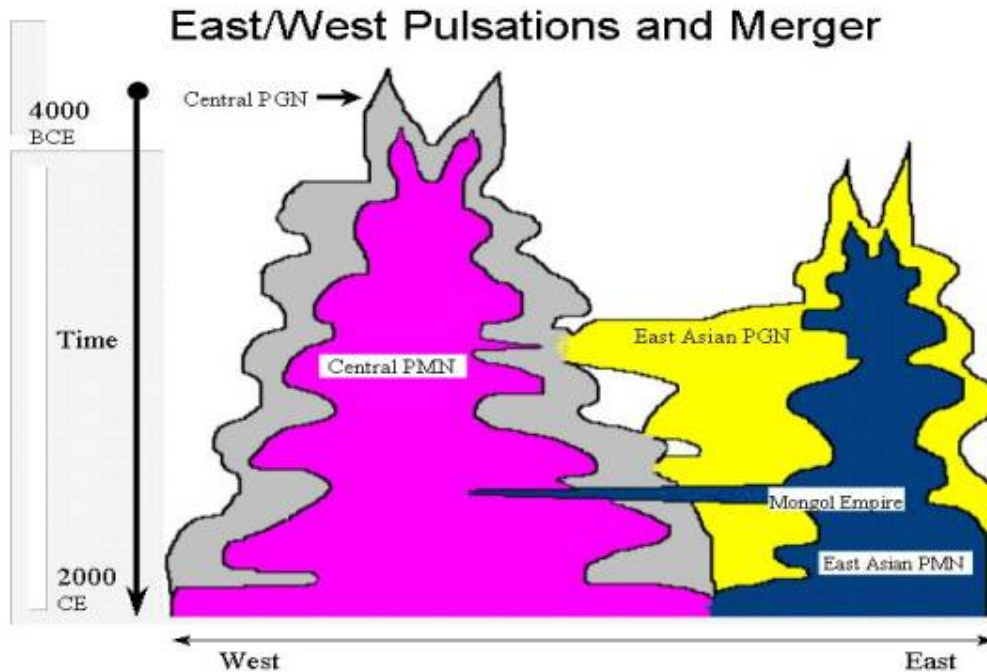


Figure 4: East/West Pulsations and Merger

### Synchronization of Empires, Cities and Demographic Waves

Earlier studies have used data on both city sizes and the territorial sizes of empires to examine different regional interaction systems and the hypothesis that regions distant from one another were experiencing synchronous cycles of growth and decline (e.g. Chase-Dunn and Willard 1993; Chase-Dunn, Manning and Hall 2000; Chase-Dunn and Manning 2002). Frederick Teggart's (1939) path-breaking world historical study of temporal correlations between events on the edges of the Roman and Han Empires argued the thesis that incursions by Central Asian steppe nomads were the key to East/West synchrony. An early study of city-size distributions in Afroeurasia (Chase-Dunn and Willard 1993; see also Chase-Dunn and Hall 1997: 222-223) found an apparent synchrony between changes in city size distributions and the growth of largest cities in East Asia and West Asia-North Africa over a period of 2000 years. That led us to examine data on the territorial sizes of empires for similar synchrony, which we found (Chase-Dunn, Manning and Hall 1999). Chase-Dunn and Manning (2002) have re-examined the city size data using constant regions<sup>[6]</sup> rather than PMNs to see if the East/West synchronous city growth hypothesis holds when the units that are compared are somewhat different. Their results confirm the existence of East/West city growth synchrony.

Here we present a new analysis of East/West synchrony that uses overall population estimates compiled by McEvedy and Jones (1975). They note a synchrony in periods of regional demographic growth and decline during the late first millennium BCE and during the first millennium CE between East Asia and the Mediterranean. Interestingly, Mc Evedy and Jones (1975:345-346) reject the idea that climate change may have caused this synchrony in favor of a hypothesis of parallel and connected technological and organizational change.

We have computed the partial correlations, controlling for year to remove the trend, of population

levels from 1000 BCE to 1800 CE among three regions. We stop at 1800 CE because the trend becomes exponential after that and would drown out earlier middle range variations. What we want to know is whether or not the middle term ups and downs, what we have called growth/decline phases, are synchronous or not. We examine four regions: East Asia, South Asia and West Asia/Mediterranean and Europe.<sup>[7]</sup> These are the same constant regions that Chase-Dunn and Manning (2002) used to study the synchrony of city growth/decline phases.

	West Asia/Mediterranean	East Asia	South Asia	Europe
West Asia/Mediterranean	1	.81 (26)	.60 (26)	.79 (26)
East Asia		1	.88 (26)	.95 (26)
South Asia			1	.92 (26)
Europe				1

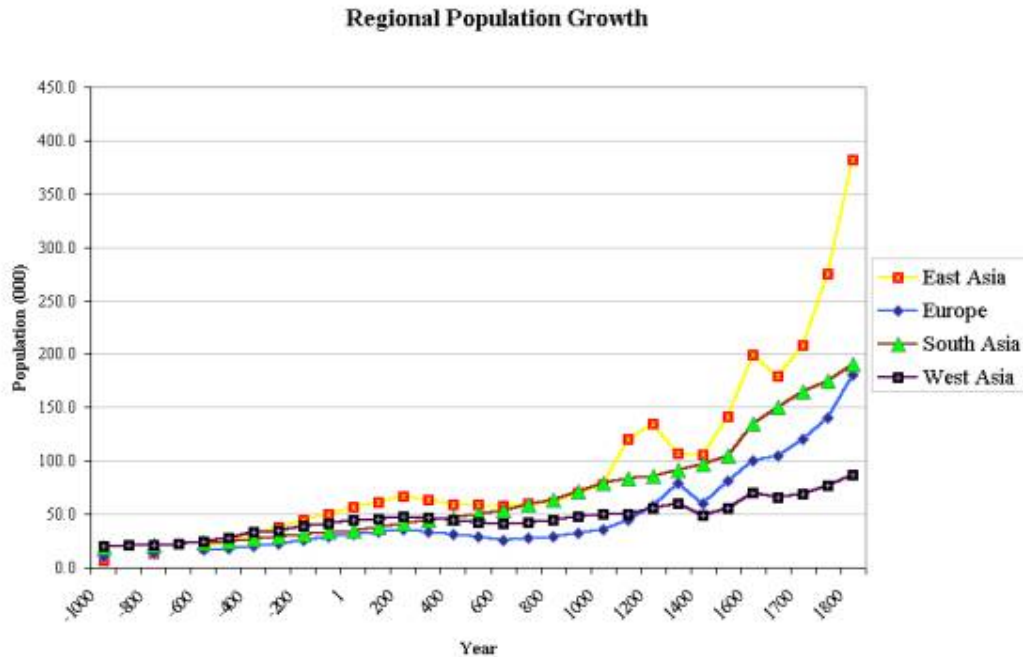
**Table 1: Inter-regional Partial Correlations of Population Change Controlling for Year, 1000 BCE-1800CE (population estimates from McEvedy and Jones 1975)**

Table 1 shows the partial correlation coefficients of population change estimates for four Old World regions. These have been detrended in two ways in order to look for synchronous growth-decline phases across regions. We eliminate the years after 1800 CE when most of the regions were undergoing geometric growth rates. And we compute the inter-regional correlations controlling for year, which should take out the long-term trend.

The results in Table 1 are somewhat surprising. There are statistically significant partial correlations among all the regions despite our efforts to take out the long-term trend. The correlation between East Asia and the West Asian/Mediterranean region is higher than that for either city or empire size cross-regional partial correlations (.81), but it is not as high as some of the other coefficients in Table 1. Curiously the correlations between Europe and both East Asia and South Asia are very high (.95, .92). The lowest correlation is between West Asia and South Asia (.60). And the correlation between Europe and the West Asia/Mediterranean region is relatively low despite that these two “regions” overlap geographically (see Footnote 7).

It is possible that these high partial correlations are partly due to the rather coarse temporal resolution of the population estimates that we have extracted from graphs produced by McEvedy and Jones (1975). Our data set is organized in one hundred year intervals, a temporal resolution that smooths out most of the growth/decline fluctuations we are trying to study. Unfortunately McEvedy and Jones do not present enough detail about the evidence they used to produce their graphs. We are looking into the possibility that this material may be obtained. Figure 5 presents the demographic data in graphical form for the same four regions.





**Figure 5: Regional Population Growth (from McEvedy and Jones, 1975)**

Examination of Figure 5 shows both the long-term trends and the shorter-term variations, though these have been smoothed by the low temporal resolution just discussed. What we see is a long hump that starts slowly in 1000 BCE and winds back down to a low point around 600 CE in all the regions except South Asia. In South Asia the slump does not appear. This is the East/West synchrony noted by McEvedy and Jones. After about 600 CE all the regions go up again, but then the patterns partly diverge. The East Asian rise is early and steeper. All the regions except South Asia display a partly synchronous decline after the twelfth century. East Asia has another decline in the seventeenth century and this is also a period of slow growth in Europe and decline in West Asia, but South Asia continues to grow in this period. The West Asian/Mediterranean region does not partake in the rapid population growth that sweeps the other regions after the fifteenth century.

### The Moran Effect in Population Ecology

The temporal aspects of climate change cycles lead easily to hypotheses about how these may be causes of certain cyclical (or at least sequential) phenomena in human affairs. And this is especially the case when cycles in distant regions appear to come into synchrony. Population ecologists have long studied the phenomenon of increases and then decreases in the population densities of plant and animal species. They model population dynamics of species within adjacent and distant “patches,” explaining how predator-prey relationships, food availability, and migration affect the cycles of population growth and decline. P.A.P. Moran’s (1953) study of the population cycles of the Canadian lynx led him to formulate what has become known as the “Moran effect” – the idea that synchronized exogenous shocks to local oscillating systems will cause them to come into synchrony even when the exogenous shocks do not themselves display much periodicity

(Ranta, *et al* 1996; Ranta *et al* 1999). Population ecologists usually have climate change in mind as the most likely source of exogenous shocks.

The important implications of the Moran effect for our problem of the causes of synchrony are that any exogenous shock can bring oscillating systems into synchrony even if the temporal features of the exogenous variable are completely different from the temporality of the local oscillating systems. A meteor impact could reset local systems and put them into synchrony. Turchin and Hall (2002) also point out that the empirical study of synchrony requires exact measurement and fine temporality, and also many oscillations and many different cases of oscillating systems in order to disentangle different plausible causes of synchrony. These are daunting requisites for our single case of East/West synchrony.

Comparable other instances of distant systems that come into weak contact with one another can be found. Within the Old World, the Mesopotamian and Egyptian core regions were interacting with one another by means of prestige goods exchange from about 3000 BCE until their PMNs merged in 1500 BCE. Chase-Dunn and Hall (2001) have already examined this case for synchronicity and have not found it, though the data on Bronze Age city and empire sizes are crude with regard to temporality and accuracy. It is also possible to study the temporality of rise and fall and oscillations in the New World. Chase-Dunn and Hall (1998b) and Stephen Kowalewski (2002) have not found synchrony between distant systems in the new world, though much more systematic and comparable research needs to be done before firm conclusions are possible.

The Moran effect implies that synchrony occurs easily because a single exogenous impact that resets systems with similar endogenous oscillations will bring them into synchrony. But if this is true we would expect to find more synchrony than we have found up to now. Population ecology also usually finds greater synchrony in patches that are close to one another than in those that are more distant (Ranta *et al* 1999), but this is not what we find in Afroeurasia. The South Asian system, intermediate between East and West, seems to be marching to its own drummer.

### Modeling Climate Change Effects on Population

Patrick Galloway (1986) models the way in which climate change can affect human population growth. He argues that it was climate change that caused the synchrony of demographic cycles noted by McEvedy and Jones (1975). Galloway's model is depicted in Figure 6.



## GALLOWAY'S (1986) CLIMATE AND POPULATION MODEL

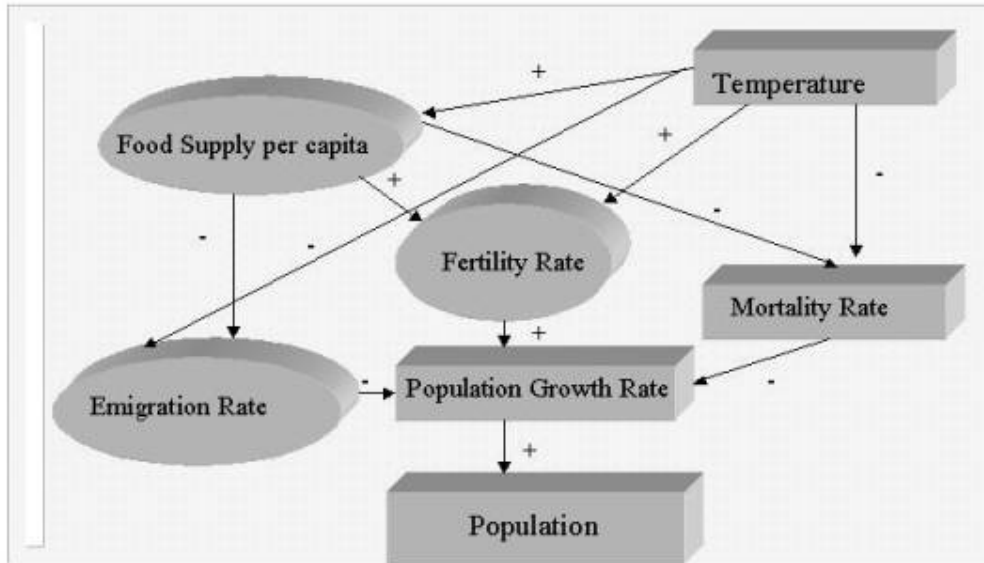


Figure 6: Galloway's (1986) Climate and Population Model

Galloway's model is entirely plausible and could easily be amended to include affects on city growth and empire-formation. But in order for this model to account for synchrony across regions the changes in temperature (and other climatological variables) would need to also be synchronous, or else there would have to at least be an initial strong climatological shift that affects all the regions during the same period. The only way to sort this out is to obtain indicators of climate change in or near to the regions we are studying in the relevant time periods. Knowing about the climate change record in Greenland will not settle the question, because despite global teleconnections, climate change is ultimately local. Our effort to gather the relevant climate change data has only just gotten under way.

### A Comprehensive Model of the Causes of Inter-regional Synchrony

We can propose a comprehensive model of all the plausible causes of East/West synchrony. The purpose of complex causal modeling is to allow us to discover the relative strengths of different causal mechanisms by examining the logic implications of causal relations and the parameters that are hypothesize to be operant. Figure 7 displays a complex causal model that contains all the hypothesized effects that result in the East/West synchrony discussed above.

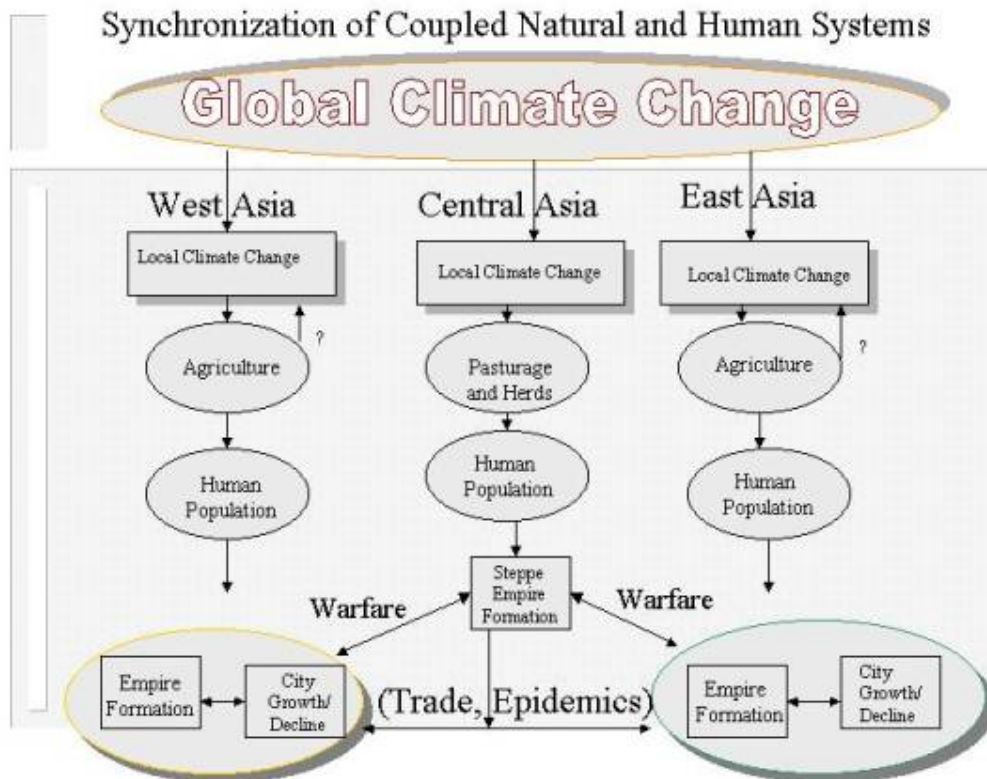


Figure 7 Comprehensive East/West Synchrony Model

This model can be translated into a complex system of structural equations and estimated parameters for these can allow us to examine the conditions under which causation can lead to synchrony. We plan to combine this theoretical exercise with a campaign to improve our empirical knowledge of the population sizes of cities and the territorial sizes of empires and climate change over the past 3000 years (e.g. Pasciuti and Chase-Dunn 2002). By approaching the problem from the angles of both induction and deduction we hope to be able to estimate the relative strengths of the different hypothesized cause of East/West synchrony. And the outcome should be a better understanding of the way in which human systems have interacted with biological and geological processes in world history.

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[1] Some social scientists erroneously assume that GIS (Geographical Information Systems) data structures are restricted to the mapping of attributes that are stationary in space and that GIS is useless for studying things that move. Geographers are now developing GIS techniques based on vectors for mapping prevailing winds, but also for studying migration (Tobler 1995; n.d.).

[2] The notion of "interaction spheres" developed by archaeologist Joseph Caldwell (1964) is another approach that recognizes that diversity has long been an important characteristic of human systems.

[3] Down-the-line trade passes goods from group to group.

[4] Kradin (2002) argues that pastoral peoples mimic the political organization of societies they are adjacent to and so Central Asian steppe empires were, in their external aspects, similar to the agrarian empires from whom they successfully managed to extract surplus product. This is a fascinating instance of a peripheral society that managed to exploit the core.

[5] If we manage to get through several sticky wickets looming in the 21<sup>st</sup> century the human system will probably expand into the solar system, and so "globalization" will continue to be spatially expansive.

[6] The earlier research on cities had used political-military networks (PMNs) as the units of analysis following the method of bounding world-systems as interaction networks. When we use PMNs the Central System expands spatially over time. Chase-Dunn and Manning (2002) reanalyzed the city data using constant regions (Near East, Europe, East Asia, South Asia) that do not change over time.

[7] The West Asia/Mediterranean region includes the whole Mediterranean littoral so as to include the whole interactive city system that originated in West Asia and spread to the Mediterranean with Etruscan, Greek and Phoenician migration and the emergence of the Latin cities. Thus Europe and the West Asian/Mediterranean region are geographically overlapping one another.